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A VISION OF DEMAND RESPONSE - 2015

PIER INTERIM REPORT

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A Vision of Demand Response – 2015

INTRODUCTION

Demand response is a complex operational resource that requires the integration of utility system operations and a wide range of customer service functions with customer operational changes. In this sense, demand response exemplifies system integration.

System integration is generally defined as the deployment of multiple systems, networks or other resources that are linked together to accomplish a common objective.

Over the last thirty years demand response programs and technologies have not realized their potential primarily because they weren't integrated into the basic utility operating and service structure.

The Programmable Controllable Thermostat (PCT) initiative being pursued by the California Energy Commission has raised numerous technical and operational issues. What functions should a PCT support? What type of communication capability should a PCT provide? What comes first, the PCT, the tariff, advanced metering, policy or something else? All of these questions reflect a basic system issue.

All of the technological and engineering features presented in these scenarios are technically feasible today. However, many of these features may not be politically feasible. This document does not address the compromise between technical and political feasibility.

An overview of the basic assumptions, policy and organizational issues is presented in the sections following the scenarios.

SCENARIOS

Scenario 1: Residential Low User, Minimum Functionality, Special Exemptions

Mrs. Meg A. Watts

Background Information

At 78 years old, Meg A Watts was excited about moving into her new condominium in the Shady Acres Lawn Bowling and Mahjong Retirement Community. Widowed a little over three years ago, her long-time home of the past 35 years was just too large and too difficult and expensive to maintain. Her grown children arranged to move her to a new home in the southern part of California's central valley, where she would have warmer weather and would be near her grandchildren. The cold Idaho winters and high winter utility bills were difficult to manage on a fixed income. Recent health problems that now required on-site 24-hour remote monitoring equipment linked to her doctor's office just added to her budget difficulties.

Her new condominium was substantially smaller than her old house in Idaho. According to her son Less, the reduced size of her new condo combined with all of the new energy efficient appliances, should lower her utility bills substantially and make it much easier to live within her budget. Less had called the utility in advance to arrange service for his mother. They asked a few questions regarding her basic lifestyle and home features and whether she qualified for any special exemptions. As a result of that call, they mailed Less an information packet and setup checklist.

Day #1: Normal Operations / Anticipated Critical Peak Conditions

Tuesday, July 21, 2015, 10:00am

Meg and her son Less made a pre-move in visit to her new home to setup the various utility, communication, and other accounts and to acquaint her with the operation of her new appliances. Meg was not a big fan of computers and automation and was initially overwhelmed by the many automation features of her new home, especially this new thermostat she read about. Less, assured her it was all quite simple, led her to the wall where the thermostat was mounted, took out the checklist provided by the utility and proceeded to show her how it worked.

Her son Less explained that about ten years ago the CPUC adopted new rate structures that charged customers what he called a critical peak rate (CPP). Most of the time she would be charged under a simple time-of-use rate, that several times each year might be augmented by a supplemental charge that reflected high utility cost or emergency situations. He assured Meg that it was actually a pretty good deal. As he explained, during the summer months, her electric utility costs would be lower during late evening to early morning hours and higher during the mid-afternoon period when people were cooling their homes. If the demand for energy ever got high enough to trigger a high-cost situation or threatened the utility's ability to provide power, they would send out a radio signal alerting all customers to a critical peak price. Less explained that customers were usually given 12-24 hours advanced notice of any pending critical peak prices, however, sometimes customers were given no advanced notice – which was the reason customers automated their response through the new thermostat.

Less explained how her thermostat would receive critical peak price and emergency signals and automatically make minor adjustments to her comfort settings based on her preferences. As part of his explanation, Less pointed out the three LED lights on her thermostat and explained to Meg what each light meant. The yellow light, which was currently lit, indicated that the thermostat was active, working properly and currently receiving a utility test signal. He showed her the little sticker attached to the thermostat that provided instructions for calling the manufacturer if the yellow light should ever go out or if the thermostat malfunctioned in any other way.

Using the checklist, Less instructed Meg to push in the Override button and hold it for a few seconds to trigger a test routine. A blue light next to the yellow light came on and slowly started flashing. Les explained this light would be activated when the utility knew in advance, like the next day, that there would be a critical peak price. After a few seconds, the blue light stopped flashing and stayed lit – he explained that a solid blue light meant the critical peak price was actually in effect. Finally, after a few seconds a third red light started to slowly flash. Less explained that this meant there was something the checklist referred to as a Stage 1 system emergency. This also triggered a critical peak price and the same pre-programmed reaction from her thermostat. Finally, the red light stopped flashing and stayed lit. Less explained that a steady red light meant there was a very serious Stage 2 power emergency, which meant that the utility was just one step away from rotating outages - when all of her power would be turned off. Meg did not need a more detailed explanation. She had been visiting Less and his family in the summer of 2000 and vividly remembered the blackouts.

After Less finished his explanation of her thermostat display, he proceeded to the next section of the checklist and told her she had three options to choose from in setting up her thermostat.

- Option 1: Live with the Default Settings – Less explained that the thermostat was preprogrammed from the factory with default settings. If she did nothing the defaults would automatically raise her thermostat setting by two degrees in summer or lower it by the same amount winter in response to the critical peak prices.

- Option 2: Modify the Default Lifestyle Settings - Less pushed the setup button and scrolled through the lifestyle settings pre-programmed into the thermostat. The lifestyle settings provided several common work, vacation, and other schedules. Because this was a retirement community, the thermostat default was pre-programmed by the builder for a weekday and weekend "At Home" schedule, with the minimum critical peak price response. Meg could easily change the start and end time of any schedule to suit her needs or change the thermostat response if she wanted to increase or decrease her critical peak savings on her electric bill.

  Less also showed Meg that the setup routine allowed her to push the override button and automatically disable the critical peak price and Stage 1 emergency response indicated by the blue and red warning lights. Disabling the price response option during the setup process meant her thermostat and appliances would operate normally all the time and she would pay whatever it cost for the energy. Less also pointed out that she could leave the automatic price response program alone and just push the override button if she ever became uncomfortable or inconvenienced during a pricing event.

  Less noticed that the utility provided checklist also included estimated billing information for his mother's new condo, apparently based on information he provided during his phone call to activate her new account. The utility estimated that his mother's new home would probably be classified as a "low user" under the 130% of baseline legislation. As a result she would get a bill each month that would charge her either the subsidized capped rate or the CPP rate, whichever was lower. The utility called this the Low Bill Guarantee Option.

Meg took Less' recommendation and decided to try the default CPP pre-programmed lifestyle settings. Pushing a single button to override any automated CPP response was easy enough and the Low Bill Guarantee Option provided reasonable financial protection. Meg stood to gain financially if everything worked right. According to the utility analysis they estimated her bill would be about 10% lower under the CPP option if she does nothing to respond. With the minimal response settings pre-programmed into her thermostat, the utility estimates Meg should pay about 15% less than she would under the subsidized 130% baseline rate.

- Option 3: Disable the Stage 2 Emergency Setting
  According to the setup checklist, Less noticed that this option was limited to individuals with health and other disabilities that might be adversely impacted by any of the Stage 2 emergency response actions. According to the checklist, the information he provided to the utility regarding his mothers medical monitoring and alert equipment during the account setup process qualified her for the exemption. With her medical conditions, exposure to extreme heat situations that might result from any prolonged loss of use of her air conditioning, might pose a health problem.

  The checklist included a highlighted box with what looked like a special bar code printed in one corner. Following the instructions, Less was directed to hold the bar code within six inches of the thermostat, hold down the override button and wait for an acknowledgment signal, indicated when all three check lights would flash once, stay lit for about three seconds and then go back to their normal mode. According to the checklist, the bar code was really a printed radio frequency identification tag that was programmed for a one-time exemption. Less followed the instructions and noticed that the yellow, blue and red lights flashed once, stayed on for about 2-3 seconds and then went back to a normal mode, with the yellow light on and the red and blue lights off.

Tuesday, July 21, 2015, 10:20am

Just as Less and his mother were finishing up at the thermostat, they saw the flashing blue light come on. Meg looked at Less and asked if that was something he did or was that a signal from the utility that tomorrow could potentially be a critical peak price day. Less responded that he was pretty sure it was a utility critical peak price alert, although he said he had a way to confirm the signal. Less pulled out his pocket communicator, a small hybrid device a little larger than the size of a deck of cards that included voice, video, calendaring, email, several entertainment options and electronic e-commerce applications. The top portion of Less' display, reserved for high priority messages, was flashing with a critical peak alert for Less' house from his utility. Less held out the pocket communicator to show his mother the flashing message. He mentioned that he had programmed his home systems to automatically forward all critical messages to him via his pocket communicator.

Day #2: Critial Peak / Emergency Conditions

Wednesday, July 22, 2015, 8:30 am

Reading the local newspaper and watching the early morning news on TV while enjoying breakfast in her new home, Meg noticed a small banner in the upper right corner of the front page announcing that today would be a critical peak day. There was even a reference to later section of the newspaper that provided a "Helpful Hints" list of things people could do to save money. The TV weather report indicated that the heat wave was continuing, forecasting another day with temperatures exceeding 100°F. As she watched the weather report Meg noticed a similar "Critical Peak Alert" banner superimposed in a corner of the TV screen.

When she checked the LEDs on her thermostat she noticed that the blue light was still flashing. Although she still felt a little uncertain regarding how this new automated response stuff would work, the information provided by the newspaper and local TV station seemed to demonstrate a rather comforting level of coordination. It seemed like the whole community was pulling together to help keep down costs and avoid problems. Meg was feeling pretty comfortable with her new home.

Wednesday, July 22, 2015, 2:30 pm

What the Customer Sees

Meg had just retuned from the local grocery store and was unpacking when she heard a brief "beep" that appeared to come from her thermostat. When she checked, she noticed that the blue light had stopped flashing and was now fully lit. According to Less, this meant that the critical peak prices were now in effect, which should trigger an automatic response from her air conditioning system. From the checklist that Les left with her she knew that her thermostat was set to 75° but now it read 77°. Meg was impressed; the thermostat had automatically responded just as Less had described. Meg went back to unpacking her groceries but mentally reminded herself to take another look a little later to make sure everything was still working right.

What the Customer Does Not See

Meg's thermostat was responding to a single secure Internet signal that originated over 400 miles away from the California ISO to her local utility when the wholesale cost of energy exceeded a distribution area critical peak threshold value for the Southern region of her central valley community. The ISO was not only monitoring wholesale prices; it and Meg's local utility were also simultaneously using the Statewide Power Management System (SPMS) to monitor in real-time the actual load and system harmonics on almost all major substations and distribution circuits. The ISO critical peak price signal was automatically dispatched based on algorithms that balance the wholesale costs with other information regarding congestion and potential reliability features for each monitored substation and distribution circuit. The California ISO signal was received almost instantaneously by Meg's host utility and was instantaneously passed through to their critical peak broadcast system which uses a side band of several public radio and television stations to trigger customer thermostats and other price responsive devices. Passing the critical peak signals through each utility provides local utilities with an opportunity to intervene and adjust the dispatch for any maintenance or other special activity that might be jeopardized by an untimely price or reliability signal. Utility operators had not flagged any of the target areas for intervention; consequently the ISO signal was passed through without delay.

Within 3-5 seconds the critical peak price signals had been received by approximately 1.5 million residences and businesses, representing approximately 12 gigawatts (GW) of load. Price and reliability conditions were not yet considered severe. Isograms established over several years of real-time load monitoring indicated that voluntary customer price response should provide more than sufficient load relief to mitigate current problems. Consequently the ISO dispatch was statistically targeted to dynamically configured groups of customers within the target area to produce a minimum 2° change in HVAC setting at any customer site. ISO algorithms were designed to dynamically configure customer groups and the control intensity to just meet the system need. Real-time monitoring creates a closed-loop response that either ratchets the control strategy up or down based on actual measured customer response.

The critical peak signals dispatched by the ISO and local utility trigger a minimum one-hour control strategy from each thermostat and price responsive device based on CEC design guidelines incorporated into the Building and Appliance Standards. The design guidelines specify two basic parameters that each device must meet, specifically:

(1) A minimum one-hour average control response. Specifying a 60-minute average control period minimizes the number of signals that need to be communicated and also avoids unnecessary short cycling of customer loads. In addition, the control period is internally randomized to average 60 minutes in duration; however, actual durations will vary between 45-75 minutes. Randomizing the duration of control helps balance returning load at the conclusion of each control event.
(2) Randomized control strategy start times. Normal critical peak price signals are received by each controllable thermostat and price responsive device almost instantaneously, however, activation of the device response is internally randomized over a 15-minute period. Randomizing the start times of each customer device helps balance both the initial load impacts and returning load at the end of the control period. In emergencies, multiple simultaneous signals from the ISO or local utility will trigger an immediate, non-random instantaneous activation of the control strategy for all customer devices.

Wednesday, July 22, 2015, 4:00 pm

What the Customer Sees
While entertaining several of her new neighbors, Meg heard another beep coming from her thermostat. When she checked, the blue light was still lit and now the red light was flashing. It was still reasonably comfortable in her home. The thermostat still showed a setting of 77°. One of Meg's new neighbors explained that the local utility must be having some problems. Meg remembered that the flashing red light meant that the utility was experiencing something called a Stage 1 system emergency. One of Meg's new neighbors then stated that she had programmed her thermostat to go all the way up to 80° during these critical peak events because of the money it saved on her monthly bill. She said, "When it gets too warm, I just go to the clubhouse or mall for a few hours." Meg decided to wait and see whether her home would become uncomfortable.

Just as she was about to rejoin her new friends, there was another beep from the thermostat. Now the red light stopped flashing and stayed lit. Meg knew from Less that this meant there was a much more severe Stage 2 emergency. However, Meg also noticed that although her thermostat setting did not change from 77° the numbers were now flashing. One of her neighbors said something must be wrong with Meg's thermostat because when she gets a solid red light her thermostat displays a flashing emergency symbol instead of a temperature setting.

One of Megs other neighbors chimed in and said, "The flashing temperature setting means that Meg must have an exemption." Meg confirmed that indeed that was the case because of the medical equipment she had in the bedroom that let her doctor and hospital remotely monitor her heart conditions.

Once Meg's neighbors figured out that a Stage 2 emergency had been called, they also realized that their air conditioning systems would automatically be locked out until the utility problems were corrected. None of Meg's neighbors had exemptions. Reluctant to return to homes that would soon be getting a little uncomfortable, Meg offered and they all unanimously decided to stay a little longer.

Then they all started talking about how complex all this technology stuff was. Meg was still confused and amazed over how what looked like a bar code on a piece of paper could actually be a miniature radio.

What the Customer Does Not See

At 3:59 pm the Statewide Power Management System (SPMS) registered a forced outage on a major supply point feeding the Southern central valley area. Dispatch algorithms at the California ISO automatically adjusted for the loss of load by instantaneously ramping up the customer price response signals. The ramping process generated multiple radio activation signals that (1) automatically bypassed local utility intervention and (2) instantaneously realigned customer groups and synchronized another round of 2° HVAC temperature increases from all controllable thermostat and other price response devices.[1] This latest round of emergency signals overrode the internal randomizing routines in customer control devices to intensify the load response. The dynamic realignment of the customer groups allowed the ISO to focus more voluntary price response on the most congested areas. Reserve margins were now below 7% in certain geographic areas but holding steady.

At 4:03pm another forced outage triggered a Stage 2 alert. This time ISO dispatch algorithms substantially ramped up the control algorithms to temporarily impose mandatory reliability overrides on all non-exempt customer HVAC loads. In this case, a severe distribution problem required the HVAC loads in the target area to be locked out entirely for the duration of the event. Almost instantly, the SPMS registered an additional 2 GW of load relief on the impacted circuits, pushing system reserve margins back above 7%.

Simultaneously, local utility systems dispatched electronic explanatory warning messages to all major commercial and industrial customers as well as others who had signed up for the notification service. Announcements were also automatically dispatched to all radio and television stations. Repair crews were also receiving information from both the utility advanced metering (AMI) network and SPMS regarding isolated customer and distribution feeder outages. Select crews received emergency electronic work orders on Internet connected field tablets that directed them to specific GPS coordinates corresponding to the location of each outage.

Wednesday, July 22, 2015, 6:35 pm

What the Customer Sees

Meg's first mahjong game was breaking up and her new neighbors were starting to leave when there was another beep from her thermostat. The yellow light was now the only one of the three that was still lit. Both the blue and red light's were now off. Meg's thermostat was registering an internal reading of 77^0 but her internal setting was now back to 75^0 . Apparently both the critical peak and emergency situations were over. Meg and her neighbors just shrugged and went about their business.

What the Customer Does Not See

Both forced outage situations were quickly resolved by emergency utility crews. By 5:45 pm power had been restored to all customer locations reporting problems. Declining commercial loads combined with voluntary and mandatory price/reliability response brought reserve margins back to normal levels. Based on forecasts from the SPMS, refresher price response signals were discontinued at 5:50pm. Forecasts showed that all customer loads would return to their normal local operating state starting around 6:30pm.

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[1] After the CEC adopted the PCT standards, many vendors and providers of automation services realized that the same price and reliability signals used to activate a PCT could also be used to control other facility loads. The CPP tariff provided a substantial economic incentive for controlling other facility loads in addition to the PCT-controlled HVAC systems.

No major outages were reported. Utility customer operating centers reported no significant increase in call volume.

Scenario 2: Residential High User, High End Options, Advanced Functionality

Mr. Less Watts

Background Information

Less Watts is a 42-year-old electrical engineer. For the last 6 years he has worked for the NanoScience Particle Energy Research and Popsicle Company (NSPERPC), a high-tech manufacturing company he started with his brother. He and his family live about five miles from his mother's new condominium in a 4,200 square foot custom built home in an exclusive neighborhood. Less is a true high-tech gadget guy. Much to the consternation of his wife and children, Less has automated and monitored very aspect of his home.

It turns out that Less' infatuation for technology is actually secondary in importance to his quest to save money. When his utility introduced critical peak pricing (CPP) about nine years ago and advertised how much money customers could save, Less took it as a personal challenge. While his initial efforts with utility recommended control devices produced reasonable bill savings and few noticeable impacts on his family's lifestyle or comfort, Less was convinced he could do better.

Less eventually discovered that his utility offered quite a few information and technology options to assist with his quest. One of the most intriguing options was a load profiling and analysis package being made available by his utility through local branch libraries. The package included a wireless display tablet and several devices that looked like miniature extension plugs. According to the literature, the wireless tablet was a full-fledged computer with several built-in communication links. With a supplemental subscription fee, the display tablet will allow Less to download and display in near real-time, his household energy usage and actual cumulative billing / cost information directly from the utility. Analysis and modeling applications included with the tablet will allow him to graphically display his usage information, customize the analysis by inputting more detailed house and appliance information, and benchmark his usage with like homes in his own community. One of the most interesting applications makes it possible for Less to monitor each major appliance one-by-one and perform sophisticated economic evaluations that identify when he should consider a more efficient replacement. This utility provided application also creates a list of certified local suppliers and installers. Applications included with the electronic tablet also automatically complete and transmit electronic applications for special rebates on new appliances that Less wants to purchase.

According to the literature, the extension plug devices represented an innovative new technology. These devices provide Less with the capability to monitor in real-time, the load for anything that has an electric cord. Each extension plug had a letter code stenciled on one surface. Plugging the extension plug into a wall socket and then plugging the appliance into the extension automatically brings up a window on the wireless tablet labeled with the letter code corresponding to the stencil on the extension plug. The window displays in real-time how much energy is being used by that appliance at that moment. By choosing the right options, Less can integrate these individually monitored loads with his total house load. Less is also provided with options to download all the data and reports wirelessly to his own computer.

The first time Less checked out the electronic tablet and load monitoring package, he was almost beside himself with excitement. First he monitored the big things like the refrigerator, furnace, washer and dryer. He then monitored everything that was plugged into the wall including his bedside lamp, toaster oven, electric toothbrush and his wife's lava lamp. Based on a rate analysis using the utility provided applications, Less discovered that properly managing his cooling zones and shifting load to off-peak time periods would substantially reduce his electric bills. The display table also allowed Less to preview and model new state-of-the-art high-tech appliances with built in demand management and other features that could be wirelessly linked with a whole-house energy management system. As a result of this evaluation, Less upgraded his HVAC, refrigerator, washer, dryer and hot water heater. He also subscribed to the advance energy management, monitoring and information services provided by the appliance manufacturer.

The new HVAC system employed wireless technologies that eliminated the need for a conventional wall-mounted thermostat. Instead, his new HVAC system came with little stick-on temperature sensors about the size of a quarter that he could mount anywhere in his house. The system also came with a wireless display/control panel that could sit on a counter or mount to a wall bracket. Besides managing his home energy use, the display panel provided a wireless link to the Internet along with several news and entertainment options. What most excited Less was the fact that neither the display panel nor any of the remote sensors used batteries – all were using a new energy scavenging technology based on visible light, sound and vibration.

The HVAC system that Less purchased included a redesign of the home duct system. Less divided his house into four zones and then retrofitted his ductwork with controllable dampers and remote temperature sensors that allowed him to establish different comfort settings for each zone. The wireless display panel displayed a schematic of his entire house with real-time monitoring of each zone. The compressor and heating units came equipped with fully integrated electronics and internal programs necessary to provide full compliance with the CEC price responsive Building and Appliance standards. When he purchased the new HVAC system, Less opted for a vendor offered premium monitoring, preventative maintenance and home automation package. This advanced package required a special hybrid Wimax bi-directional communication capability that would allow the vendor to support remote system diagnostics, off-site remote maintenance and a range of other appliance applications, as well as enhancements to the State required price responsive and emergency response functions.

For all of his other major appliances, Less opted for models that were wirelessly linked to and controlled by the home energy monitoring and maintenance package provided by his HVAC vendor. Linkages between the appliances and the home automation system provided support for pre-cooling, shifting water heater use to off-peak hours and low-power critical peak interlocks for the washer, dryer and dishwasher. According to the simulations provided by the HVAC vendor, Less could theoretically reduce his peak summer month electric bills by up to 40%.

Day #1: Normal Operations / Anticipated Critical Peak Conditions

Tuesday, July 21, 2015, 10:20am

What the Customer Sees
Less' wife Lesley was in the kitchen paying bills and monitoring local news updates they had programmed into the wireless display monitor when a blinking critical peak alert appeared in the upper

portion of the screen. The message included a small icon provided through their appliance vendor home energy management subscription. When Lesley tapped the message with her finger, a window with supplemental information appeared. The message indicated that the critical peak period was most likely to occur tomorrow, Wednesday, July 22nd between 2:00 to 3:00pm and would last for about 90 minutes. The message also indicated that all in-home systems and control settings were operational. There was also a status message indicating that the operating systems, environmental controls and energy management functions at Less' business (NSPERPC) were online and also operating as planned. Lesley knew that Less would get these messages automatically since he programmed the wireless display to forward all messages to his pocket communicator.

<u>What the Customer Does Not See</u>
By 5:30am each morning the ISO operations center has received the first of several real-time updates from the Statewide Power Management System (SPMS). Real-time substation and feeder data, together with weather forecasts, monitored system harmonics, historical circuit loading and current trading data produce a forecast of potential system cost, market price and system reliability conditions for a range of geographical and critical transmission / distribution locations throughout the statewide electrical network. With a continuing heat wave, several forced outages and other supply constraints; the forecast anticipates potential critical price conditions for the next day during the later afternoon hours. As a result, by 10:00am that morning, the ISO has provided each local utility with a critical peak alert and detailed forecasts for Wednesday, July 22nd.

After processing the ISO information, the local utility dispatched a system wide critical peak alert through their communication providers, who in turn sent signals to all CEC compliant controllable thermostats and price responsive devices.

Less Watts purchased appliances and subscribed to information and management services that require a more sophisticated communication capability than that mandated in the basic CEC compliant devices, consequently his systems do not receive the standard utility "Critical Peak Alert". Less' vendor provides their own communication network that receives the utility "Critical Peak Alert" and then passes it through to each of their subscribers along with additional information necessary to manage Less' preferences. Less' vendor received their certification as a Qualified Signal Provider from the CPUC only after demonstrating they could meet a specific list of performance criteria.

<u>Day #2: Critial Peak / Emergency Conditions</u>

<u>Wednesday, July 22, 2015, 8:30 am</u>

Less and Leslie Watts left for work around 7:30am a few minutes after their kids ran out the door to catch the school bus. Although the house was now empty, Less' energy management program is beginning the second phase of his bill management routine. Phase 1 began around 4:00am, when the water heater began pre-heating water in anticipation of the family's regular morning schedule. Before she left for work, Leslie placed a load of dirty clothes in the washing machine and filled the dishwasher. Timers on both appliances were pre-set to start and complete their cycles before the peak rating period began at 11:30am. Phase 2 of the energy management schedule included the following:

8:30am – The dishwasher starts its 90-minute cycle and the HVAC system begins pre-cooling Zone 1, which includes the kitchen and family dining areas. Pre-cooling lowers the temperature in Zone 1 from its normal 78° set point to 72° and then establishes a maximum set point of 80° for the peak hours of 11:30am to 6:00pm. The pre-cooling start time is automatically determined by the home energy management system. The system automatically monitors inside and outside temperatures and determines that precooling will take about three hours and conclude just before the peak rating period begins at 11:30am. The dampers and sensors in HVAC Zones 2-4 have been programmed to keep temperatures at or below 76° during the pre-cooling period. The dampers will be closed and no cooling load will be provided to Zones 1-4 during the peak hours unless temperatures exceed 84°. The precooling schedule and minimum-maximum temperature settings were established by iterative routines in the vendor provided home energy management system.

9:45am – The water heater begins a heating cycle both to supply the washing machine that is scheduled to come on at 10:00am and to pre-heat water for the post peak period hours when the Watts family kids are cleaning up and preparing their evening meal.

10:00am – The close washer automatically begins its 45-minute cycle. Less used the home energy management system to interlock the operating times of the clothes washer and dishwasher to prevent them from coming on at the same time. While Less' utility rate doesn't provide any financial incentive to minimize off-peak demands, it seemed like the efficient thing to do.

11:30am – The dishwasher, clothes washer and water heater are interlocked to stay off during the entire peak period. The HVAC system has completed its pre-cooling cycle with Zone 1 reporting a temperature of 72° and Zones 2-4 reporting 76° . The refrigerator automatically goes into low power mode.

By 11:30 am, the Watts household load has been minimized and is registering about 0.5 kW, where it will stay until the peak period concludes at 6:00pm. Zone temperatures, the status of each appliance and the household load are displayed on the monitor sitting on the kitchen counter.

Wednesday, July 22, 2015, 2:30 pm

The Watts house is quiet. The display monitor emits an audible beep and the message in the upper portion of the screen changes to report that a critical peak period is now in effect.

Wednesday, July 22, 2015, 4:00 pm

The Watts house is still quiet. The display monitor emits an audible beep and the message in the upper portion of the screen now reports that the local utility has called a Stage 1 system emergency. The Watts home energy management system verifies that the appliance interlocks are still active and all Zone temperatures are within the established settings – no action is required.

At 4:01pm the display monitor emits a series of beeps. The message in the upper screen begins flashing that a Stage 2 emergency is now in effect. The Watts home energy management system, in compliance with State code, automatically places a minimum 60-minute non-over-rideable lock on the HVAC system.

Wednesday, July 22, 2015, 6:15 pm

At 6:15pm Less Watts and his two children arrive home. Both kids are hot and dirty from after-school activities. They dash off to their rooms to change into their bathing suits and then head out to the pool. Temperatures in their bedrooms, in Zone 3, are registering 84°. On their way through the kitchen to the pool both kids complain to their father of being too hot. Less notices that the monitor is reporting a Zone

1 (kitchen) temperature of 81°. He also notices the flashing message in the upper portion of the screen reporting that a Stage 2 emergency is still in effect. Less grabs a cold drink from the refrigerator and joins his kids in the pool.

At 6:35pm the display monitor emits another audible beep and the message changes to report that the Stage 2 emergency is over. The Watts home energy management system slowly brings up the HVAC system, first in Zone 1 and then progressively in Zones 2-4. The refrigerator goes back to normal operation and immediately begins making ice and cooling water.

When Leslie retuned home at 6:45pm, the kitchen temperature was registering 79°. She quickly joined the rest of her family at the pool.

Scenario 3: Large Commercial / Industrial Scenario

MegaOffice

Background Information

Mega Office is one of the largest high-rise commercial office complexes in the downtown area. It provides premium office, conference and limited retail space for top financial, legal and other service organizations. In 2005 Mega Office volunteered to participate in a field trial for a demand response program referred to as "AutoDR". They were concerned about the mandatory CPP rates being adopted as part of a CPUC regulatory proceeding and wanted to investigate potential options that might provide them with better energy cost management capabilities. Participation in the AutoDR program turned out to be much more productive than they anticipated.

As part of the recommissioning step, where all of their environmental, internal operating systems and energy management system were tuned up and recalibrated, they discovered a number of operating inefficiencies that when corrected immediately resulted in substantial energy and bill savings. They also were able to identify relatively easy measures to support short-term price-based demand response that included resetting cooling tower temperature set points, modulating air handling equipment and temporarily turning off decorative and unnecessary lighting. The AutoDR approach worked so well that Mega Office expanded the automated control systems to include more of their lighting and air handling equipment.

In 2006 the distribution circuits supplying Mega Office and other major business establishments in the area encountered congestion problems that resulted in several emergency calls from their utility warning of potential short-term outages. Instead of just arbitrarily dropping load or closing parts of their facilities as they had in the past, Mega Office and several other businesses activated their preprogrammed AutoDR response. The resulting load reductions proved effective, buying sufficient time for their utility to complete system upgrades and avoid any disruptive outages.

Following those events, Mega Office's utility instituted a revised AutoDR package linked to CPP and to local system emergency conditions. By 2009 most business establishments with energy management systems had established AutoDR programs capable of responding to CPP price or utility emergency calls.

As part of their utility service package, Mega Office was provided with wireless access to the 15-minute interval data from the half-dozen meters serving their facility. Internet links to a utility application database also provided them with capability to monitor their actual bill in near real-time. This information was linked into Mega Office EMS and simultaneously provided to both the corporate offices in Minnesota and to the corporate energy consultants in Georgia.

Access to other utility provided applications and databases provided Mega Office with technical and financial tools for evaluating the latest lighting, building automation and environmental systems.

Day #1: Normal Operations / Anticipated Critical Peak Conditions

Tuesday, July 21, 2015, 5:30am

Mega Office's building supervisor was just completing his review of the energy management system (EMS) daily diagnostic reports and their latest quarterly corporate evaluation of the facility energy costs. All systems were operating within acceptable parameters. Enhanced automation systems installed last year now provided detailed diagnostics for every major control point in the facility. These new systems also included several automated 'self-healing' routines that automatically kept systems properly calibrated.

10:20am, Tuesday, July 21, 2015:
Mega Office's building supervisor logged in a utility provided critical peak alert for Wednesday, July 22nd. To make sure they were prepared, he initiated a diagnostic test of their new multi-level AutoDR response strategies. Expanded automation of building systems now made it possible for them to identify separate price and emergency response protocols. Due to contractual requirements in their tenant leases, Mega Office price response strategy was designed to produce no more than a 10-15% reduction in facility load. Iterative testing over the years showed that a 10-15% short-term reduction was possible without violating lease conditions or creating tenant discomfort or inconvenience. Mega Offices emergency response strategies were designed to produce a much larger 20-30% reduction in facility load. Supplemental ISO emergency surcharges added in to their underlying utility rate made it economically very attractive to increase their emergency load reductions. Mega Office's reduction also improved the likelihood that any emergency would not progress to a full rotating outage, with much more severe economic and operating consequences. EMS diagnostics indicated that all AutoDR routines were operating as planned.

Because of the day-ahead warning, the building supervisor activates a pre-cooling strategy for the following day. Enthalpy controls will start bringing in outside air to pre-cool the eastern zones of the building during the early morning hours. Building HVAC systems will provide supplemental cooling based on weather forecasts to bring the zone temperatures to pre-defined set points that should be sufficient to let Mega Office substantially reduce demand through the peak period and coast through at least part of the late afternoon critical peak hours.

Day #2: Critial Peak / Emergency Conditions

Wednesday, July 22, 2015, 5:30 am

Mega Office's building supervisor has been monitoring the pre-cooling effort that started about one hour earlier. Enthalpy controls started bringing in cooler outside and lowering internal building space temperatures from their standard 75° to 70°. The eastern facing zones are being pre-cooled first because they get the morning sun. All remaining building zones will be rotated in until the pre-cooling routine shifts over to building mechanical systems sometime before 9:00am.

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Wednesday, July 22, 2015, 8:30 am

By 8:30am the entire Mega Office facility has been pre-cooled to the target set point. Email alerts from their local utility appear on the supervisor display monitor confirming critical peak likelihood later in the afternoon.

By 10:00am, building mechanical systems are providing the first cooling to some of the eastern facing retail areas, which are experiencing higher than expected foot traffic.

By 11:30am, the building EMS has settled into its normal peak-off peak building management pattern.

Wednesday, July 22, 2015, 2:30 pm

At 2:30pm a message from the local utility alerts the building supervisor that the critical peak price is now in effect.

Mega Office Author program had begun to slowly ramp down lighting levels in most of the building public and private areas starting at 2:00pm, so that by 2:30pm most non-critical lighting is operating at about 65% of its regular load. Under the AutoDR operating strategy, cooling tower set points are raised, several of the less necessary elevator banks and all decorative lighting and fountains have been curtailed. According to the EMS, building load is leveling off at between 88-90% of the previous day's load. Temperatures in portions of the western zones are beginning to rise above the normal set point target. Because of the critical peak, temperatures will be allowed to rise to 77°, or 2° above their normal set point. The EMS forecasting applications project that because of the outside heat, building mechanical systems will have to ramp back to full capacity by 4:00pm.

Wednesday, July 22, 2015, 4:00 pm

At 4:00pm Mega Office's building supervisor received the Stage 1 emergency message from his local utility. The Stage 1 alert automatically triggered Mega Office Phase 2 AutoDR energy management strategy. Additional banks of non-essential lighting were turned off while others were reduced to roughly 50% of their normal level. Cooling tower set points and interior temperatures were raised another 1°.

Within two minutes, the Mega Office building supervisor received the Stage 2 emergency message. The EMS automatically switched substantial portions of the Mega Office load to onsite gas powered emergency generators, dropping the building load to roughly 45% or its normal 4:00pm demand.

By 4:30pm, the end-of-day routine was well under way with approximately 20% of the building tenants headed home. Building loads started their normal late afternoon decline. By 5:30pm approximately 40% of the building tenants were gone, load had declined substantially, interior temperatures had stabilized and the emergency generators were being ratcheted back to about 50% of their previous operating level.

Wednesday, July 22, 2015, 6:15 pm

At 6:35pm the Stage 2 alert ended, all the emergency generators were shut down and Mega Office EMS went into a recovery mode. All interior temperatures and other building operating systems were back in full evening operation by 8:00pm.

ASSUMPTIONS

Basic Assumptions: Utility Company

Background Information

AMI system wide implementation together with development of the SPMS has provided the investor-owned and municipal utilities with a wide range of system operating and customer service applications. As a result, customer information systems (CIS), billing, outage management, maintenance management, trading, and forecasting have all undergone major application changes.

A variety of customer information services have been introduced, including graphical bill analysis and Internet and hard copy subscription-based load data and cost analysis. One of the more innovative services is a wireless display that can be rented from local utility and local community library facilities. The display provides customers with near real-time load monitoring and billing information for their account. Customers usually subscribe to this information service for one or two months at a time when they have a billing problem due to an unexplained usage patterns or when replacing a major appliance. Embedded applications and databases, accessible through the display device can be used to help customers evaluate the potential bill impacts of various appliance upgrades and other efficiency alternatives. Applications allow customers to model the potential energy and cost impacts on their facility, to identify potential rebates, store locations, installers and financing options. Reports can be downloaded to their own computer or mailed by the utility. Customers can also link into the same utility databases and applications using their own wireless displays or home computers and subscribe to the service for a nominal cost.

Day #1: Normal Operations / Anticipated Critical Peak Conditions

10:00am, Tuesday, July 21, 2015:
As part of their normal daily operating procedure, customer service representatives, distribution engineers and trading staff review the forecasts of yesterday’s operations along with 24, 48 and 72-hour forecasts of weather and system load conditions at all major transmission and distribution locations within their service territory. ISO Advisory Warnings are also noted and logged.

Customer service representatives notice the forecasts predict a continuation of the heat wave through the end of the week. Internal supplemental forecasts identify a higher than acceptable potential for critical peak cost increases. In addition, data monitoring activities indicate that certain feeders are approaching threshold conditions that might lead to unacceptable voltage and other reliability problems.

10:15am, Tuesday, July 21, 2015:

While reviewing the daily operating reports, customer service representatives received the ISO critical peak advisory for their Southern Central Valley region. This automatically triggered a utility generated "Critical Peak Alert". Critical peak alerts are broadcast through their communication provider to all PRD's in the targeted portion of their service area, posted to the utility web site, reported in a banner in local newspapers and distributed to targeted critical customer lists by email. Critical peak alerts provide customers with advance notice of expected critical peak pricing events. They also encourage customers to review their facility operating systems and make sure their backup generation and AutoDR emergency response options are in good working order. These alerts also provide customers with PRD devices advance notice that higher prices may be forthcoming.

SPMS reports also highlighted several distribution feeders that were potential candidates for heat and cooling load problems. As a result, tree trimming and maintenance crews were redirected today to accelerate scheduled work on the most severely impacted areas.

Day #2: Critical Peak / Emergency Conditions

11:01am, Wednesday, July 22, 2015

Critical peak price alerts for Thursday, July 23rd are automatically received by the customer operations center. Critical peak price alerts automatically generate a series of computerized action plans that identify price alert maps (PAM) by substation and feeder. PAMs identify which groups of substations and feeders should receive critical peak price alerts based on their relationship to supply, T&D and existing system maintenance activity. PAMs also identify and recommend customized dispatch strategies by substation and feeder locations to account for the potential duration and intensity of potential critical peak price alerts.

Operators carefully review the PAMs and modify the recommended strategies to reflect more current information regarding distribution and other system maintenance activity. Ongoing transformer replacement and tree trimming activities in two critical areas necessitate modifications to the PAM to balance loads and avoid interfering with critical upgrades.

12:00 noon, Wednesday, July 22, 2015

Operations supervisors have reviewed and approved PAMs for Thursday, July 23rd. Operators activate the PAM and critical peak price alerts are automatically dispatched through a sideband of the State emergency broadcast system and through all registered signal providers to the targeted substation and feeder locations as well as to licensed third-party signal providers.

Basic Assumptions: California ISO

Background Information

Each morning, analysis models, linked into the real-time database maintained by the Statewide Power Management System (SPMS) produce dynamic reports comparing transmission, substation and selected feeder loads for the previous five days with forecasted loads for the next three days. The SPMS was actually designed as a series of independent systems and databases that are maintained by each utility (investor owned and municipal) linked through the Internet.

Analytical models at both the ISO and utilities continually integrate and evaluate generator availability, maintenance schedules, and outage information together with weather, actual load, voltage and frequency, and measurements of other system harmonics into hierarchical reports to support resource trading desk and other system operating and emergency activities. The SPMS reports provided to ISO system engineers include substantially refined estimates of expected supply, demand and the status of reserves throughout the state.

Automated routines under the SPMS conduct daily system tests to calibrate PRD emergency capability by substation and select-feeder locations. Equivalent to the notch tests conducted for the original air conditioning load control programs back in the early 1980's and 1990's, SPMS PRD daily tests randomly dispatch a minimized emergency signal that either increases (summer) or decreases (winter) residential and commercial/industrial HVAC settings by one degree, just enough to temporarily drop each connected load to allow measurement by real-time metering located on each substation and feeder circuit. SPMS PRD test signals occur at different times each day and at most last for minimum HVAC cycles, which is usually less than 10 minutes. Interval load, temperature, voltage, frequency and other system harmonics are automatically archived in a master databases maintained by each utility. Utility master databases are linked into the ISO via high-speed wireless Internet connections.

The database of SPMS PRD test results accumulated over the last five years provides the ISO with the capability to construct isograms that estimate the emergency load available by hour and temperature at each major feeder location. The database of isograms plotting PRD controllable load are dynamically integrated into emergency dispatch algorithms that allow system operators to target and scale emergency load relief to specific feeder and delivery point needs.

Dynamic algorithms link to real-time monitoring of each targeted area provide a closed loop confirmation and adjustment function to assure achievement of emergency load objectives. Using threshold criteria to trigger activation, dynamic algorithms use historical isograms to automatically determine the optimum control strategy for each feeder. Control strategies balance the HVAC temperature change and available customer load necessary to protect the system. With real-time monitoring, the dynamic algorithms can compare the actual load reductions achieved with the load reductions needed and instantaneously adjust the control strategies automatically upward or downward to maintain system balance. Because of the large amount of load under control, emergency PRD operations only rarely result in HVAC temperature changes of more than one degree during a typical two-hour event and generally no more than two degrees during a four-hour event.

Dynamic algorithms under ISO supervision, can automatically schedule emergency PRD load reductions hours in advance to anticipate potential loading problems due to supply demand imbalances or voltage and frequency problems. Real-time monitoring under the SPMS also allows fully automatic PRD dispatch based on threshold criteria during system emergencies.

Day #1: Normal Operations / Anticipated Critical Peak Conditions

10:00am, Tuesday, July 21, 2015:
As part of their normal daily operating procedure, system engineers review the forecasts of yesterday's operations along with 24, 48 and 72-hour forecasts of weather and system load conditions at all major transmission and distribution locations.

Although parts of the state have been experiencing a prolonged heat wave, forecasts do not yet highlight any immediate system imbalances or potential emergency situations. Although supplies are tightening and reserve margins and system costs are still within acceptable limits, forced outages of several utility and customer resources are highlighted by SPMS reports as a potential problem area. As a result, the forecasts indicate that load; weather and supply conditions could trigger a critical peak price event in the Southern Central Valley regions during the hours from 3:00 to 5:00pm on. Wednesday, July 22nd.

Because of the tightening supply conditions and projected load forecasts, at 10:05am the ISO authorized the issuance of critical peak advisories through the California State Reliability Exchange (Reliability Exchange) for all utilities in the affected regions Critical Peak Advisories encourage utilities and customers to prioritize critical system maintenance activities and tune up internal systems that might be needed should prices and reliability conditions worsen. The ISO critical peak advisories were dispatched through a secure Internet connection to all utilities and other load serving entities.

The Reliability Exchange is a secure Internet site maintained by the ISO that provides open access to ISO price and reliability forecasts on a weekly, daily and hourly basis accessible to energy utilities, consumers and energy / demand response providers. Secure portions of the Reliability Exchange provide automatic notification and coordination between the State investor owned and municipal utilities and licensed third-party signal providers.

Day #2: Critical Peak / Emergency Conditions

10:00am, Wednesday, July 22, 2015:
Due to restricted supply conditions, Cal ISO forecasts estimate 200-400 percent increases in peak hour prices for Thursday afternoon, July 23, 2015. Reserves on Tuesday briefly dipped below 10%. With today's expected high temperatures and critical peak prices forecasts don't look good for Thursday. Reserves are projected to be very close to the 7% threshold and SPMS reports indicate that any additional forced outages would trigger reliability events. SPMS monitoring shows that critical congestion has now spread out of the Southern Central Valley region into the entire Central Valley, the Southern desert and throughout the entire LA basin.

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Cal ISO system operation models estimate that customer price response will produce peak load reductions of 8-12 percent, which should be more than adequate to maintain system reserves. Continuously updated load and system harmonic data from the real-time SPMS confirm that up to 25% of targeted substation loads are available through the emergency PRD system should supply and/or other system conditions worsen. Forecasts target and identify specific substations and distribution points where supply / congestion problems will be most severe.

11:00am, Wednesday, July 22, 2015:
Cal ISO 24-hour price forecasts and a critical peak price alert for Thursday, July 23rd are automatically posted and dispatched via the Internet to the Reliability Exchange.

Basic Assumptions: California Public Utilities Commission

Background Information

As a result of the CPUC decisions in 2006 that made Critical Peak Pricing (CPP) the default tariff for all customers, demand response (DR) and energy efficiency (EE) were now fully integrated into all customer service agreements. The CPUC also updated utility outage management plans to reflect the emergency system protection capability included under CEC Building and Appliance standards for price responsive devices (PRD) and functionality.

Both the time-of-use and critical peak components of the CPP rate provide customers with clear incentives to evaluate efficiency investments. Incorporating the critical peak prices in the tariff provides customers with clear incentives to consider major appliance and other purchases that accommodate load shifting and automatic reductions in response to either price or reliability events.

Establishing CPP as a default tariff also simplified what had been a twenty-year menu of continually changing utility sponsored DR programs. Under the CPP tariff customer incentives come from avoiding the use of expensive energy during critical peak times. Customer incentives are now directly related to how each customer changes their energy own usage pattern, not whether they sign up for a specific DR program. Rewarding customers for performance rather than participation had several other major positive impacts. First, because customers were now avoiding the use of high cost energy, utility revenue requirements and rates went down. Plus, removing the need to pay customer incentives for avoided utility costs lowered revenue requirements and rates. Most significantly, the artificial boundaries imposed by previous rate DR program structures were now eliminated, allowing each customer to do as much or as little as they wanted in defining how they would respond. The CPP tariff eliminated the overlapping incentives and restrictive participation rules that characterized the previous mix of a rate and DR programs. Implementation of the CPP tariff also eliminated many of the utility sponsored EE subsidies.

A review of EE cost effectiveness revealed that CPP improved the return on investment and accelerated payback periods for most critical lighting and HVAC related applications. As a result a variety of new subsidies were developed to overcome purchase resistance and financing rather than long run cost effectiveness. Utilities efforts to integrate EE and DR were now much easier given the simplified price signals provided by CPP. Utilities EE and DR activities switched from program management to customer education, customer information services, the evaluation of alternative automation and efficiency upgrades, and vendor and product referral services – efforts to emphasize and assist customer adaptation to the CPP tariff.

Rate impact studies showed that CPP rates were easier for customers to understand. Rate stability over the last nine years also provided more certainty that made residential and commercial/industrial (CI) investment in EE less risky for all major lighting, HVAC and facility automation related modifications. Targeted subsidies for renewable and distributed generation, facility automation, and other selected options continued to be supported on an as-needed basis. A few ISO supported reliability-based options also received continuing support.

The integration of DR and EE under the CPP rate also eliminated the restrictions previously imposed on the Public Goods funds. While the public goods charge was reduced by about two-thirds several years ago, the remainder was now directed to support utility directed customer education, information services and product evaluation and certification tasks in support of both EE and DR.

A Vision of Demand Response – 2015

A recently released CPUC report confirmed that the price responsive device (PRD) functionality standards imposed under the CEC Building and Appliance Standards was now producing substantial energy conservation as well as demand response impacts. While prior studies showed that approximately 60-70% of all customers were not using the basic programmable capability of their existing thermostat, opting instead to manually control temperature settings, new utility studies now show that only 25% of the customer population continue to operate in the manual mode. The remaining 75% have implemented one or more of the default lifestyle settings required by the Building and Appliance standards

Utility and ISO studies also conclude that customer price responsive; non-reliability capability under the CPP tariff is producing 6-8% reductions in gross summer peak system load in response to day-ahead notification. Voluntary reliability responsive capability under the CPP tariff and PRD operation is producing 12- 18% reductions in gross summer system peak load in response to day-of notification.

Utility and ISO studies also confirm that system tests of PRD emergency, non-override operations can consistently produce 30-35% reductions in gross summer peak system load on selected feeders in high temperature zones and 8-15% reductions in peak load on selected feeders in winter.

Utility outage management reports show steady reductions in outage frequency, duration and better targeting of tree trimming and other general maintenance dollars – producing increases in net system benefits over original projections from AMI and related business case studies. Utility reports indicate reductions of almost 50% in unserved kWh per outage due to faster recovery for the projected time period to-date.

Load and reliability analysis for selected feeders continue to show substantial potential for distributed generation at targeted office parks and retail centers, based on enhanced customer monitoring of AMI data. As a result, CPUC decisions continue to authorize increases in the allowed contribution of DR as a reliability resource under resource adequacy guidelines.

An emerging development was the recent formation of an industry driven organization to investigate the potential for DR reliability-based trading credits. Worsening transmission and distribution congestion in several geographic areas spurred manufacturers and high tech companies to evaluate options for further improving system reliability and power quality. An industry-funded report highlighted the opportunity created by common transparent system wide rates and the success of PRD's. The report points out that corporate subsidies to further improve non CI price and reliability response on selected distribution circuits could be less expensive than investing utility ratepayer funds or paying to upgrade their own sites. The industry organization has indicated they will be soon be filing an application for a targeted demonstration pilot on a critical feeder in Northern California.